Bill Morse
11/12/2003

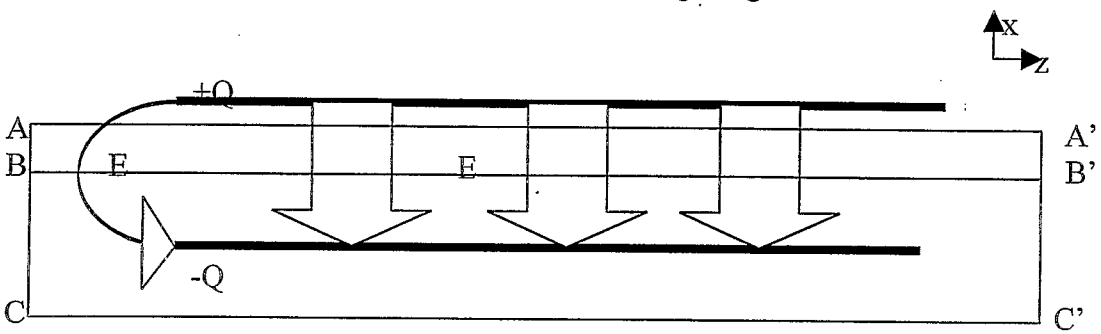
Effect of Fringe Field on EDM Experiment

William Morse and Yannis Semertzidis - BNL

October, 2003

If the electrodes are not continuous, there will be a fringe field, as shown schematically in Fig. 1.

Fig. 1. Plan view of electric field electrodes illustrating fringe field.



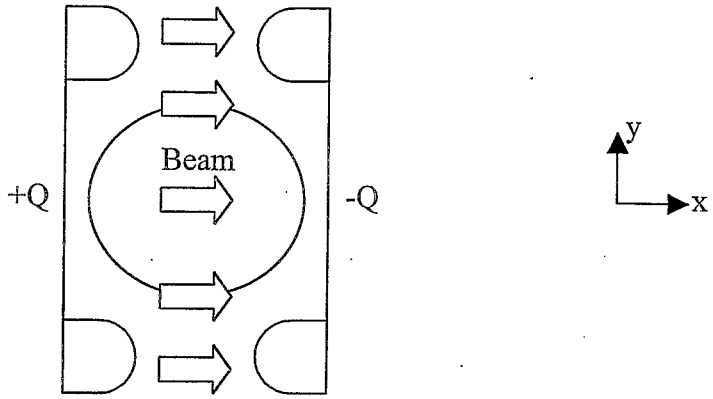
One might expect that the average electric field component E_x would be quite different for particles entering close to the plates (A-A') compared to in the middle of the plates (B-B'). However, by Gauss' law:

$$\int \vec{E} \bullet \vec{dS} = \frac{Q}{\varepsilon_0} \qquad < E_x > = \frac{\sigma}{\varepsilon_0 L}$$

where σ is the charge per unit height, L is the distance A-A' = B-B', the fringe field is negligible at points A, A', B, and B', and $<E_x>$ is the average x component of the electric field over the distance L. Particles entering close to the plates will experience an electric field component E_z which will accelerate them; however, they will be de-accelerated when they leave the electrode structure. On average there is no change in energy.

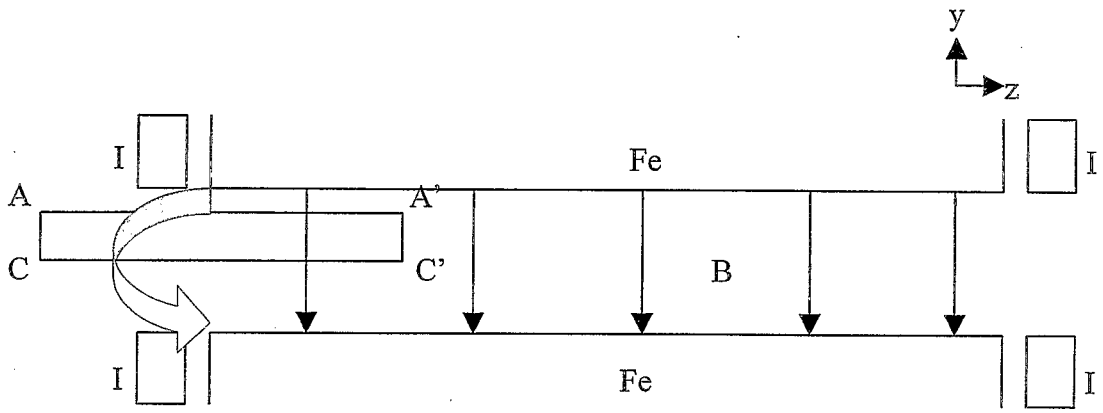
The particles on the different paths A-A' and B-B' in Fig. 1 do not experience a differential vertical component of the field E_y, by symmetry, for infinitely high vertical electrodes. However, for finite height electrodes, they do experience a vertical component of the field if they are close to the electrodes at the top and bottoms of the plates. For this reason, the top and bottom electrodes should be shaped to minimize this effect, as shown schematically in Fig. 2. This then is reduced to a design problem.

Fig. 2. Elevation view diagram of electrodes.



If the magnets are not continuous, there will be a fringe field, as shown schematically in Fig. 3.

Fig. 3. Elevation view diagram of magnet illustrating fringe field



Integrating the magnetic field over a pill box A-A'-C'-C with width ε, where the integral over the side surfaces such as (A-C')ε gives zero by symmetry, and the fringe field is negligible at A and C:

$$\int B \bullet dS = 0 \quad < B_y >_{A-A'} = < B_y >_{C-C'}$$

Particles on the path A-A' do experience a component B_z, which is canceled when they leave the magnet.

In conclusion, the fringe field due to finite electric and magnetic elements do not pose a first order problem for the edm experiment. The second order effects will have to be studied carefully and feed into the detailed design.